Johnson Matthey
Catalysts

Diesel Particulate Filter Technology for Low-Temperature and Low-NOx/PM Applications

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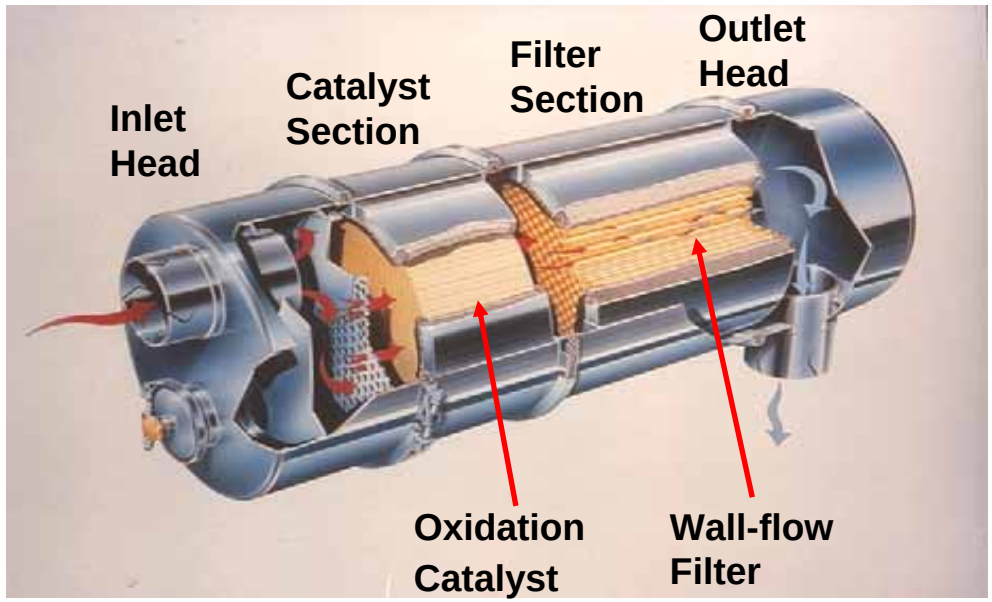
Johnson Matthey Catalysts
Environmental Catalysts & Technologies

Outline

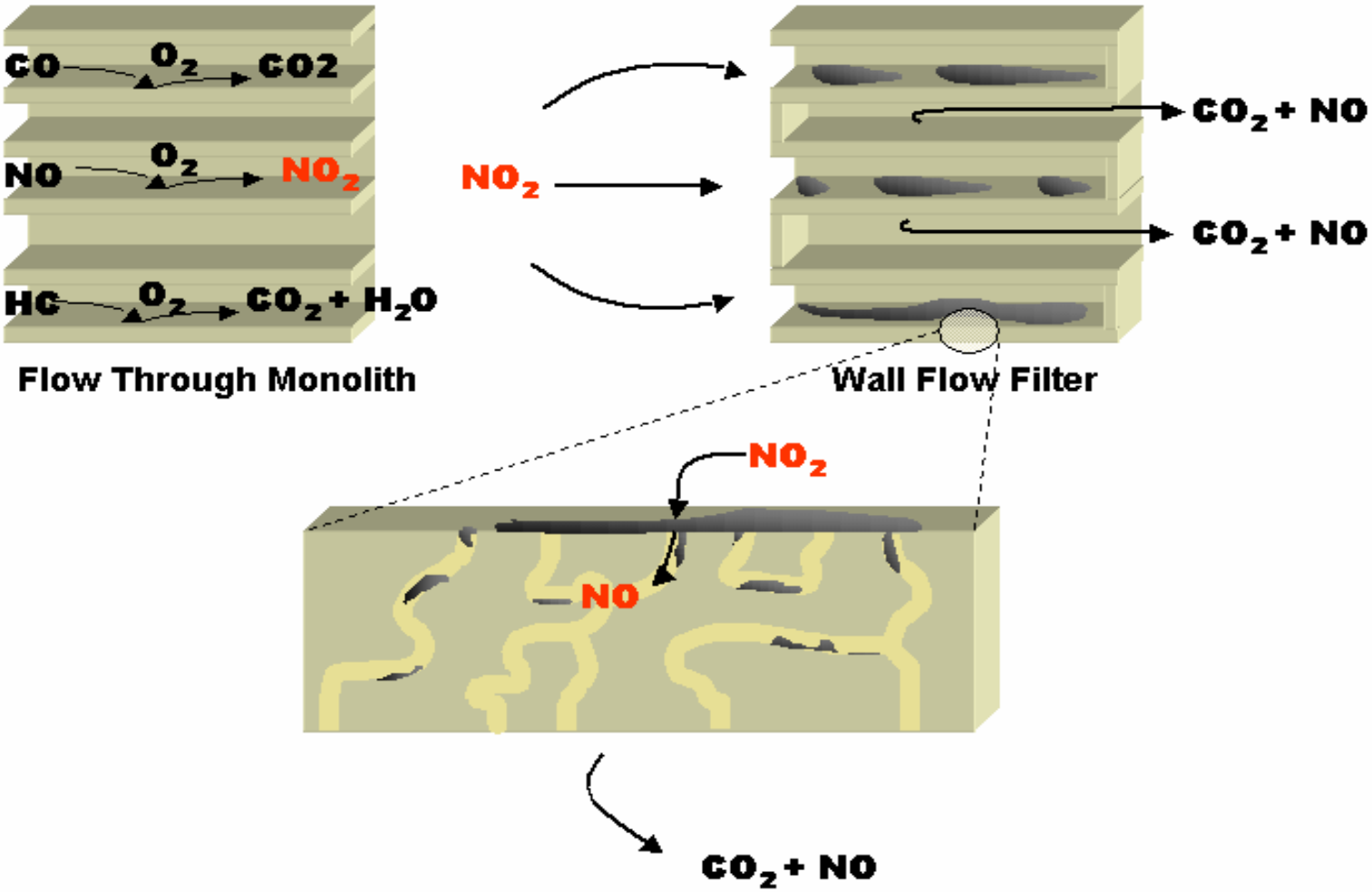
- Introduction
- CRT Filter System
  - Operational fundamentals
  - Application issues
- Active Regeneration Technologies for DPF
  - Low Temperature
  - Low NOx/PM
- Advanced CRT with Passive Regeneration
  - Low Temperature
  - Low NOx/PM
- Conclusions

Diesel Particulate Filter

- Johnson Matthey Continuously Regenerating Technology (CRT®) Diesel Particulate Filter

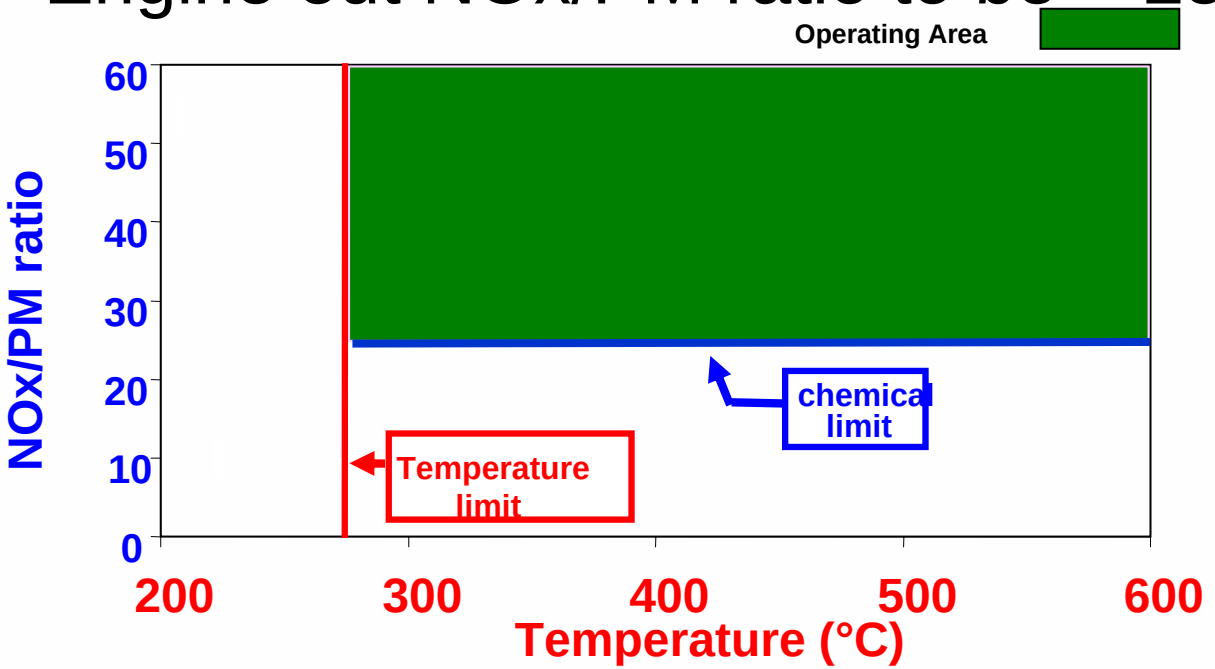


CRT System – Operating Principle



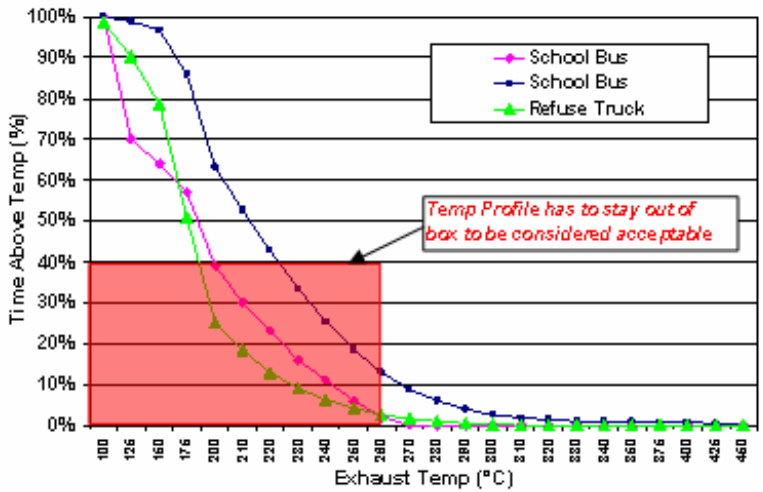
CRT System - Operational Guidelines

- CRT system operating requirements
  - Exhaust temp > 260°C for 40% of the operating time
  - Engine out NOx/PM ratio to be > 25.



CRT System - Application Issues

- Low operating temperature
  - In retrofit, low exhaust temperature can restrict the applications of CRT
  - viz. Large engines with low hp – MACK E7 300 hp, CAT 3126 175 hp



CRT System - Application Issues

- Engine out low NOx/PM ratio emissions
  - 2.5 g/bhp-hr NOx engines can have NOx/PM ratios that are < 20
  - Older engines

Possible Solutions

- Active regeneration of DPF system
  - Actively increase engine out exhaust temperature to allow NO2 based regeneration
  - Actively increase temperature to combust soot with O2
- Enhanced passive regeneration of DPF system
  - Catalytically promote combustion of soot with NO2 at lower temperatures
  - Promote the reuse NO/NO2 to combust soot in the DPF

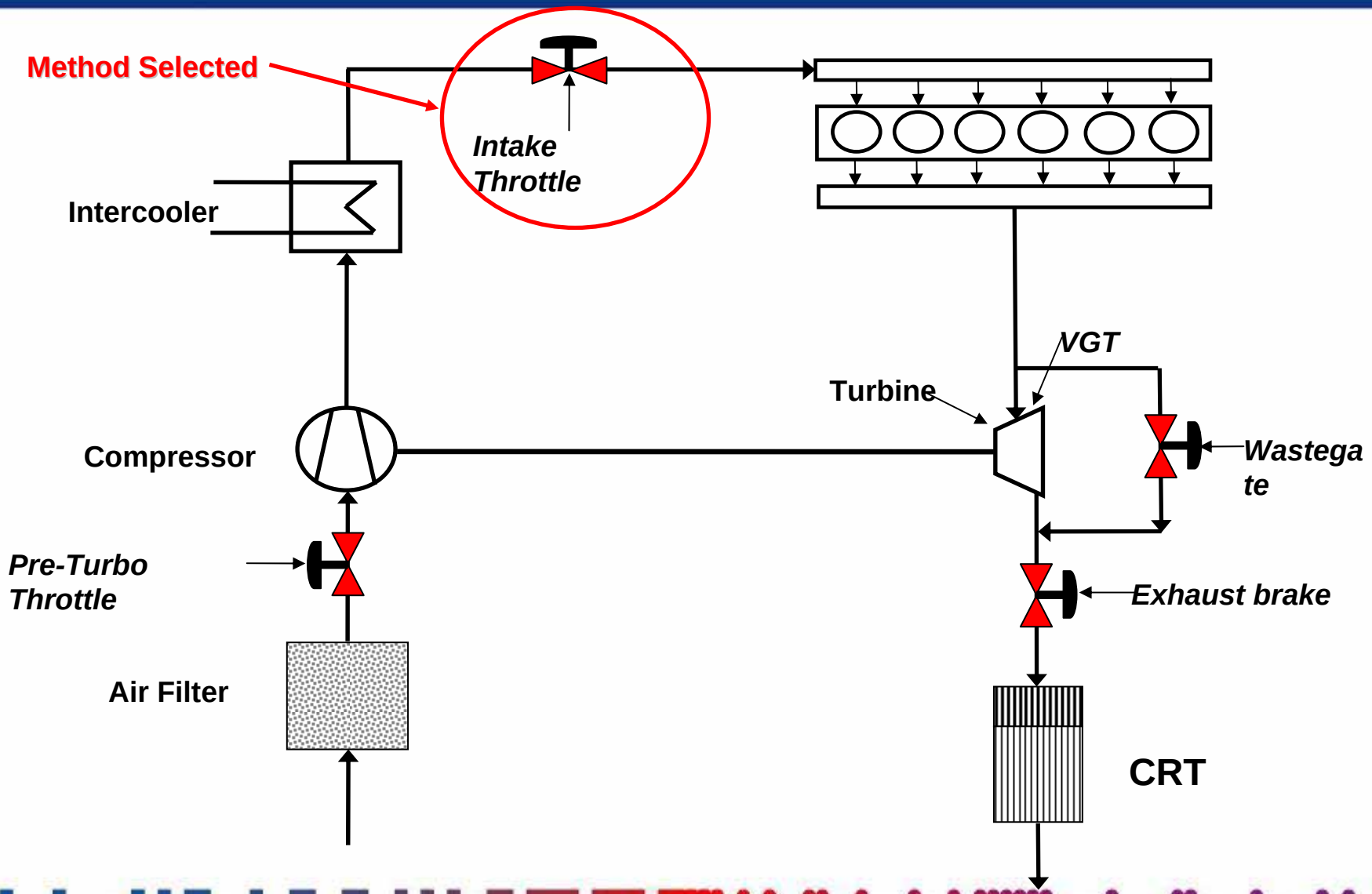
Active Regeneration of Filter System

Potential Active Regeneration Strategies

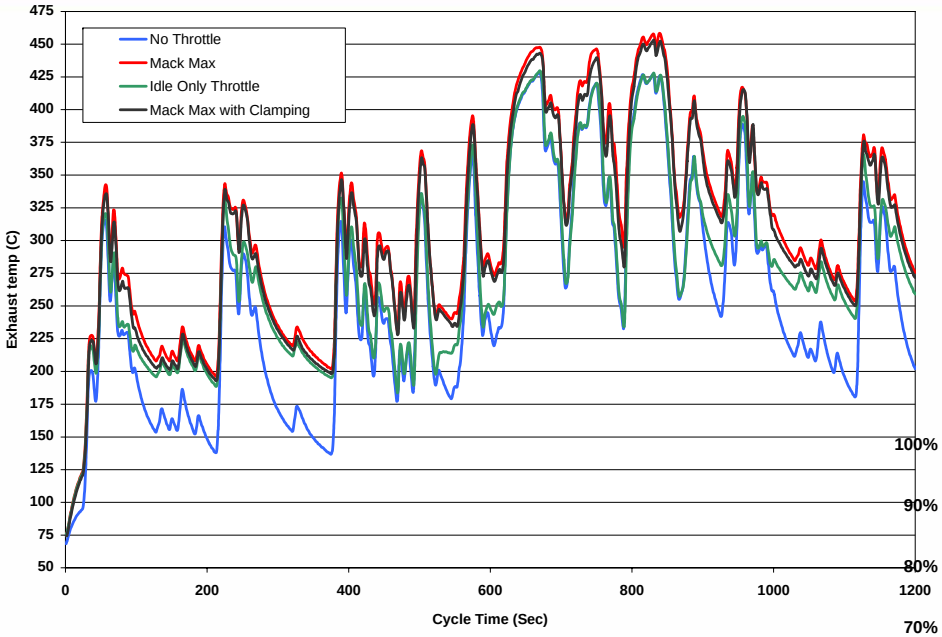
- (a) Moderate Temperature Regeneration (300-350oC) with NO2
  - Air Restriction
  - Fuel Injection
  - Takes relatively long time (lower soot burn rate)
  - More frequent on-set or longer operation
  - Safe strategy
- (b) High Temperature Regeneration (550-600oC) with O2
  - Fuel injection
  - Burner
  - Rapid regeneration
  - Less frequent on-set
  - Potential risk of filter damage from exotherm

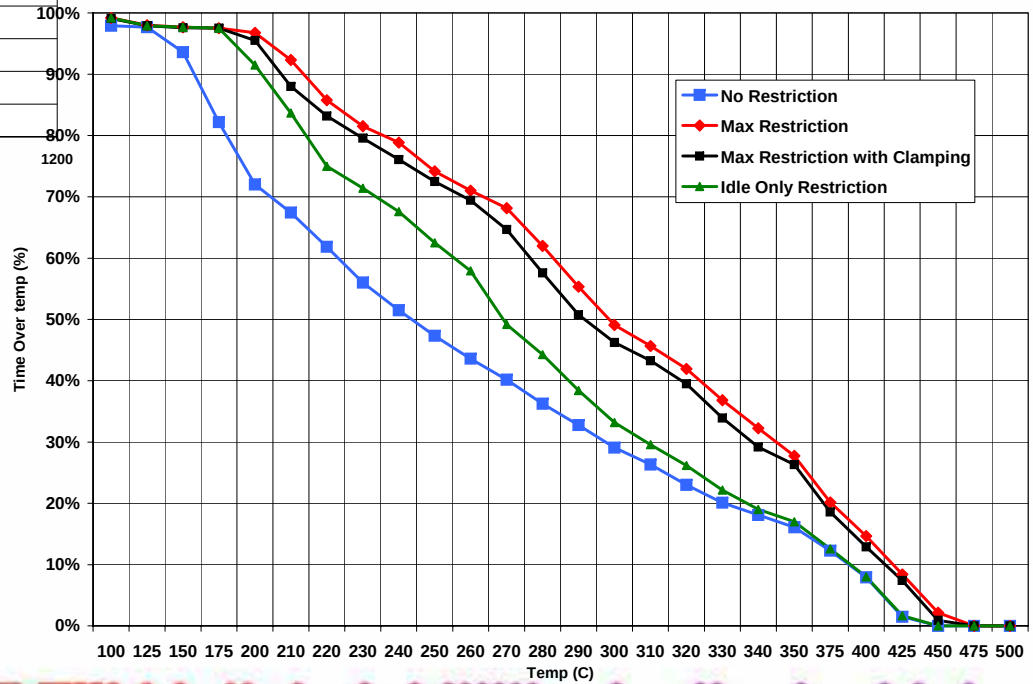
Active Regeneration:
Cold Temperature Applications

Active Regeneration Methods Using Air Restriction

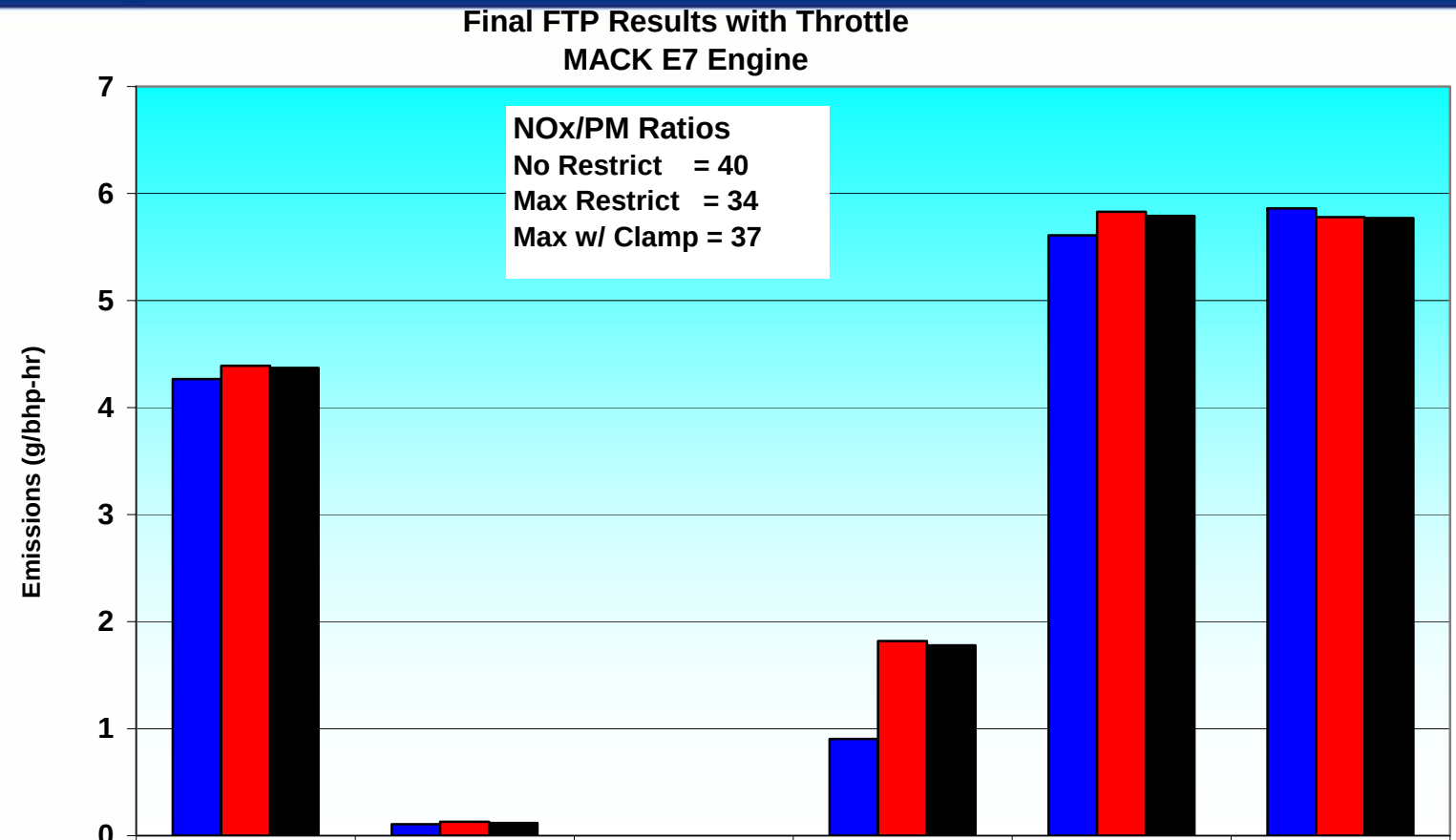


Increase in Turbo Out Exhaust Temperature with Intake Throttle FTP Testing on MACK E7 Engine





Effect of Intake Throttle on Engine Emissions
FTP Testing on MACK E7 Engine

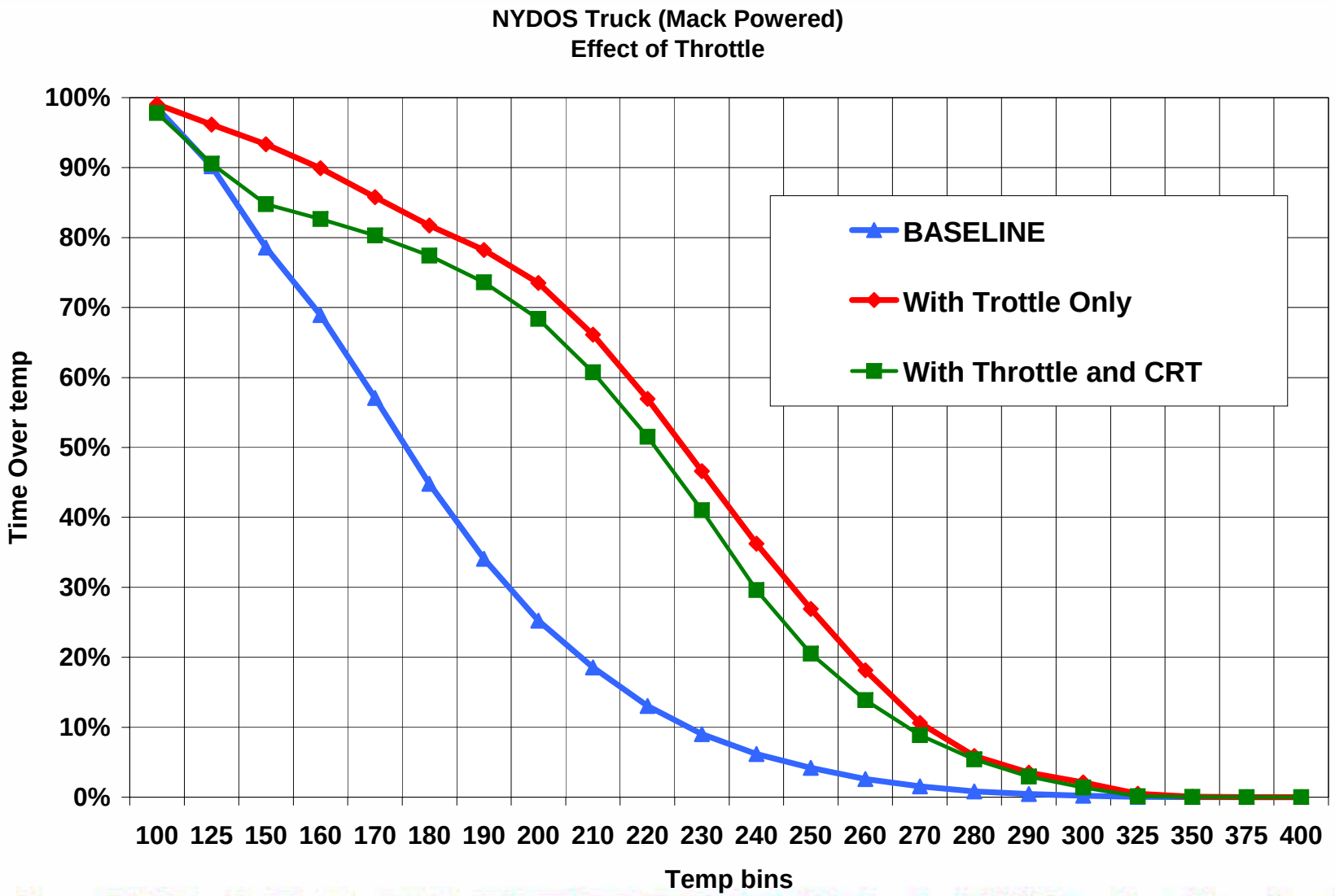


	NOx	PM	Fuel (/100)	CO	CO2 (/100)	Power (x10 bhp)
No Restricition	4.265	0.107		0.903	5.61	5.86
Max Restriction	4.39	0.131		1.82	5.83	5.78
Max w/ Clamp	4.37	0.119		1.78	5.79	5.77

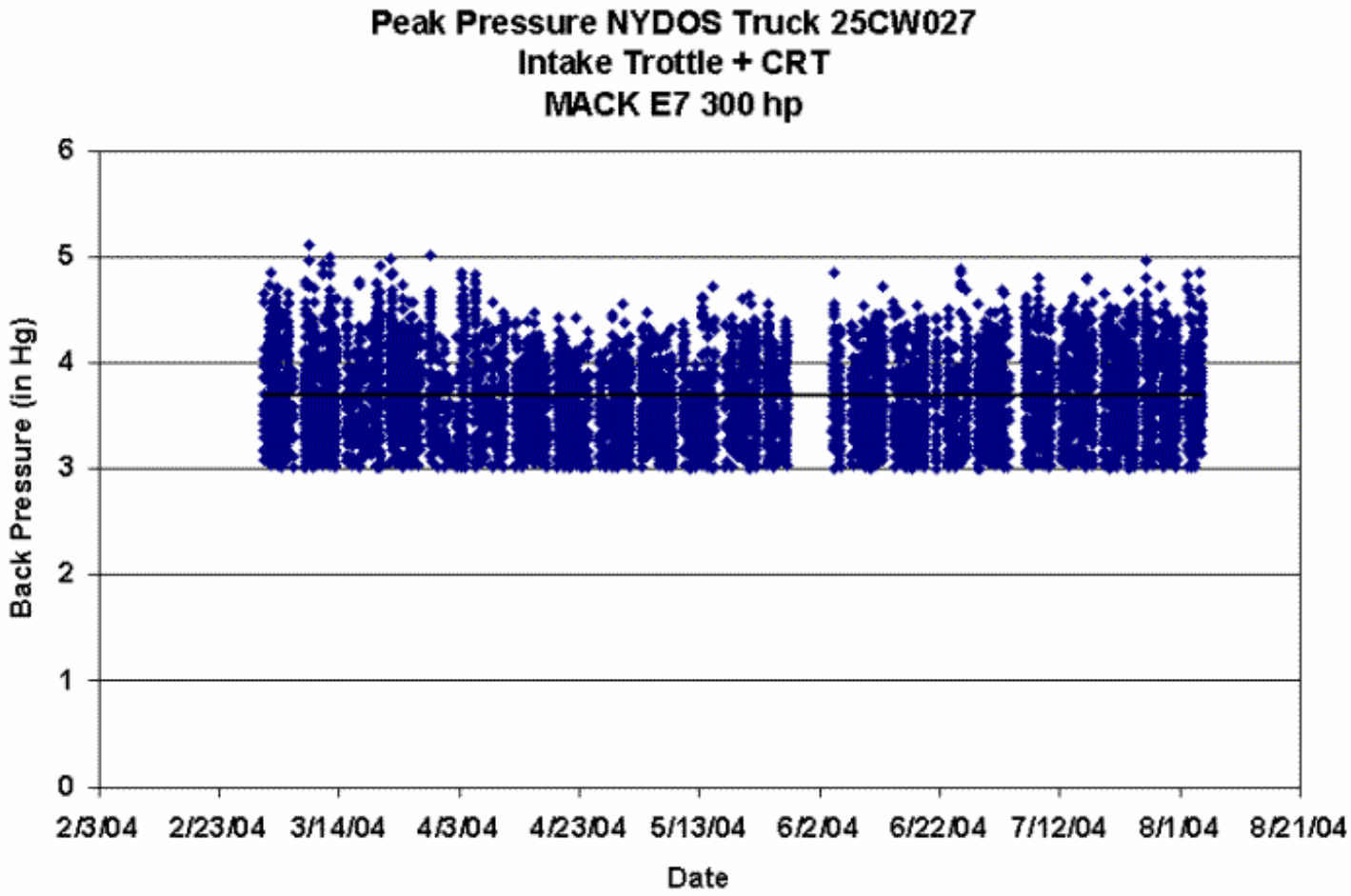
Active Regeneration of CRT with Intake Throttle System

- Mack trash truck with Heil body
  - 2000 MY
  - Engine E7
  - 12 liter in-line 6 cylinder rated at 300 hp at 1950 rpm

Throttle System Performance – Significant Increase in Temp Profile

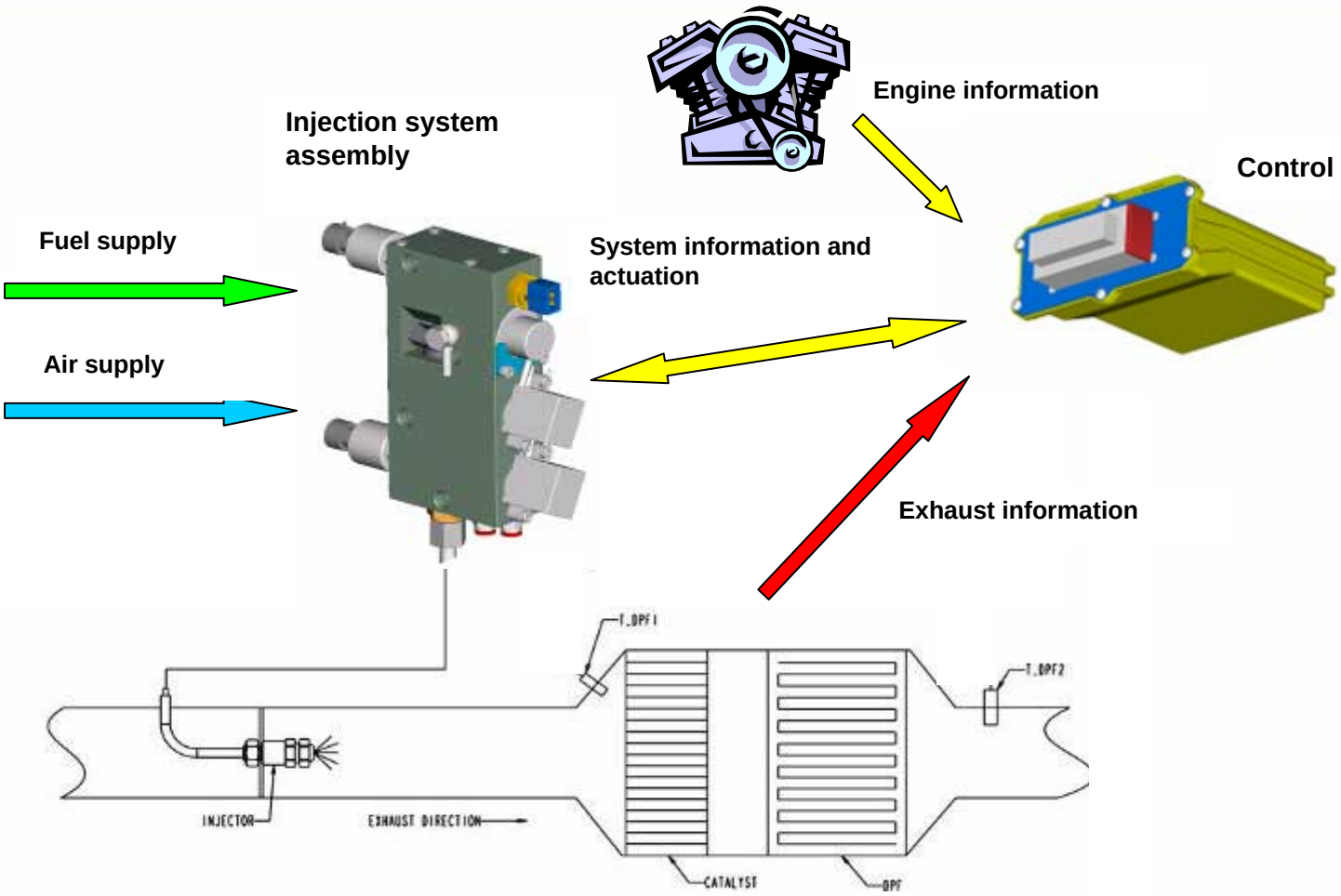


Throttle System Performance – Stable Peak Backpressure with CRT



Active Regeneration:
Low NOx/PM applications

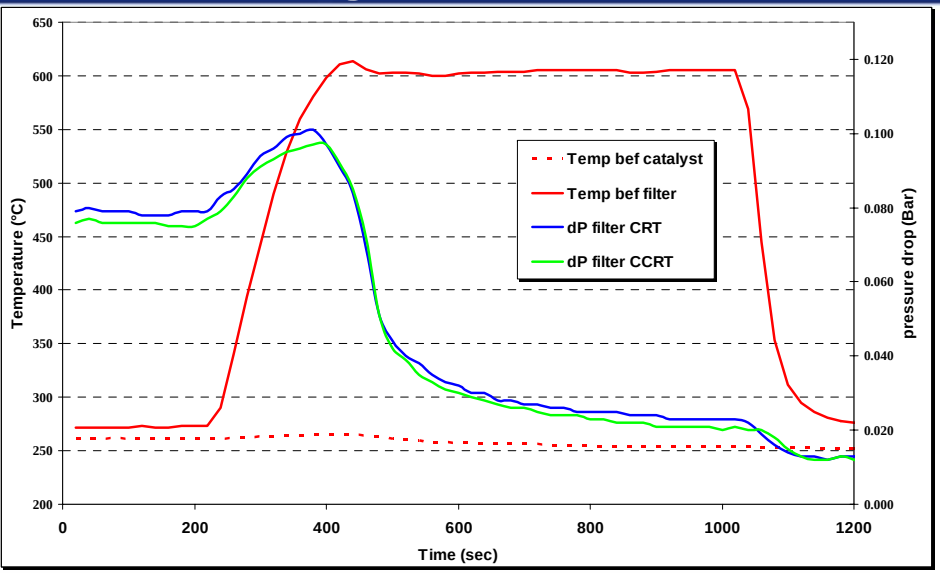
Active Regeneration with Fuel Injection



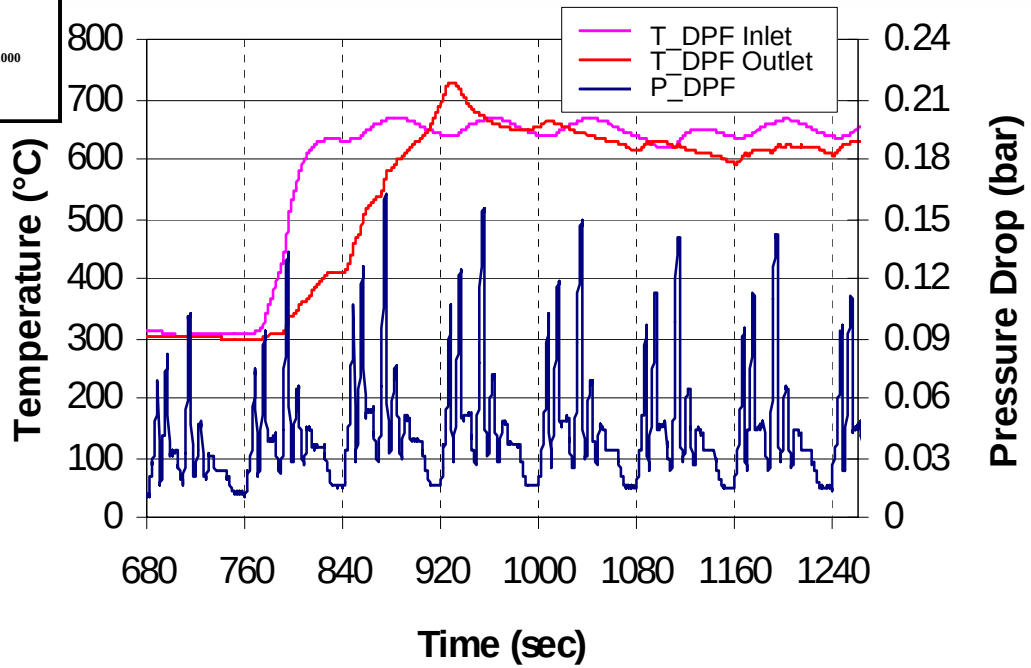
Catalyst and DPF

Courtesy: stt emtec

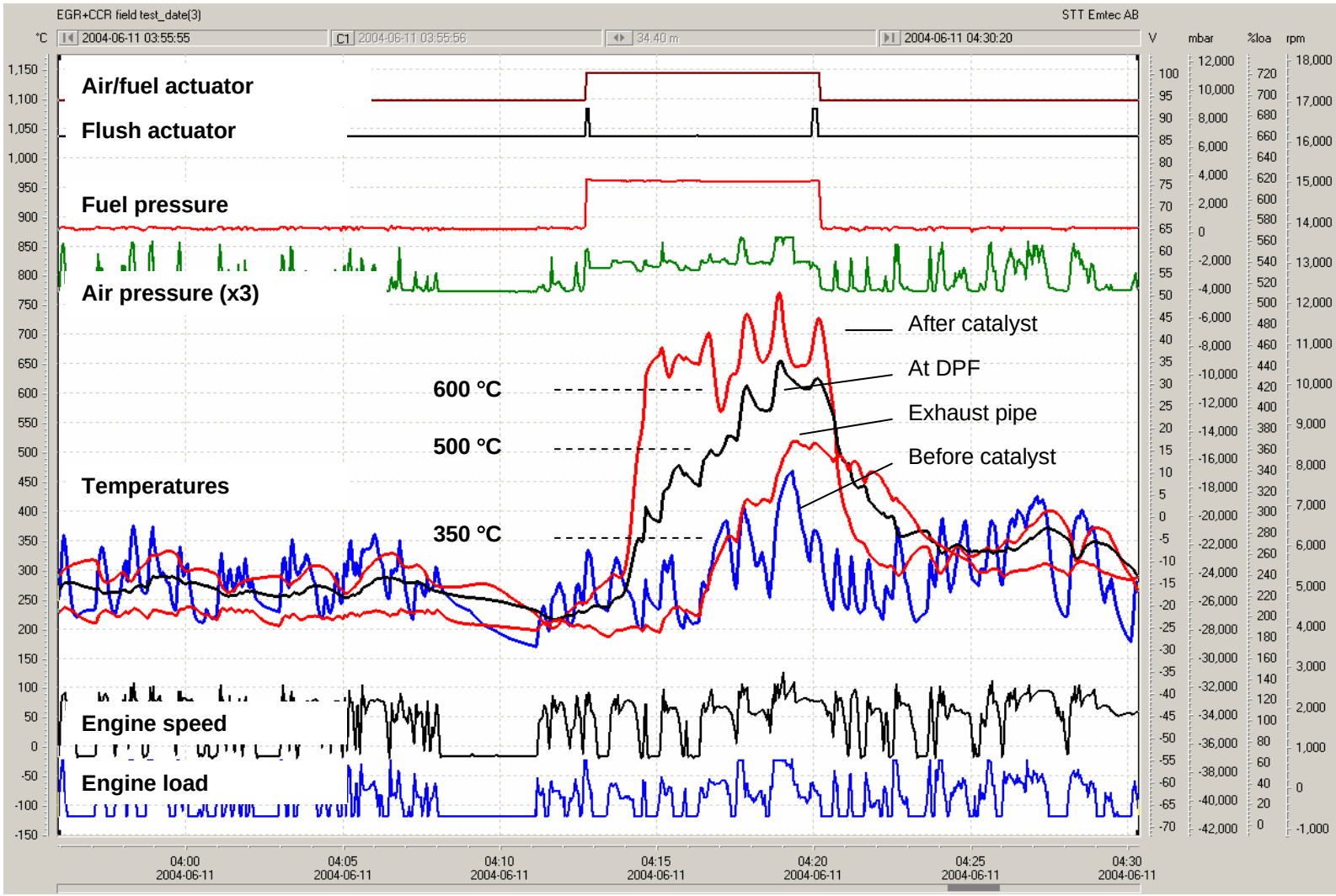
Active Regeneration of CRT Using Fuel Injection



- Soot combustion with O_2
- Filter temp > 600 C
- Typical 400 – 600 sec. regeneration cycle
- Fuel injection optimized to avoid HC slip

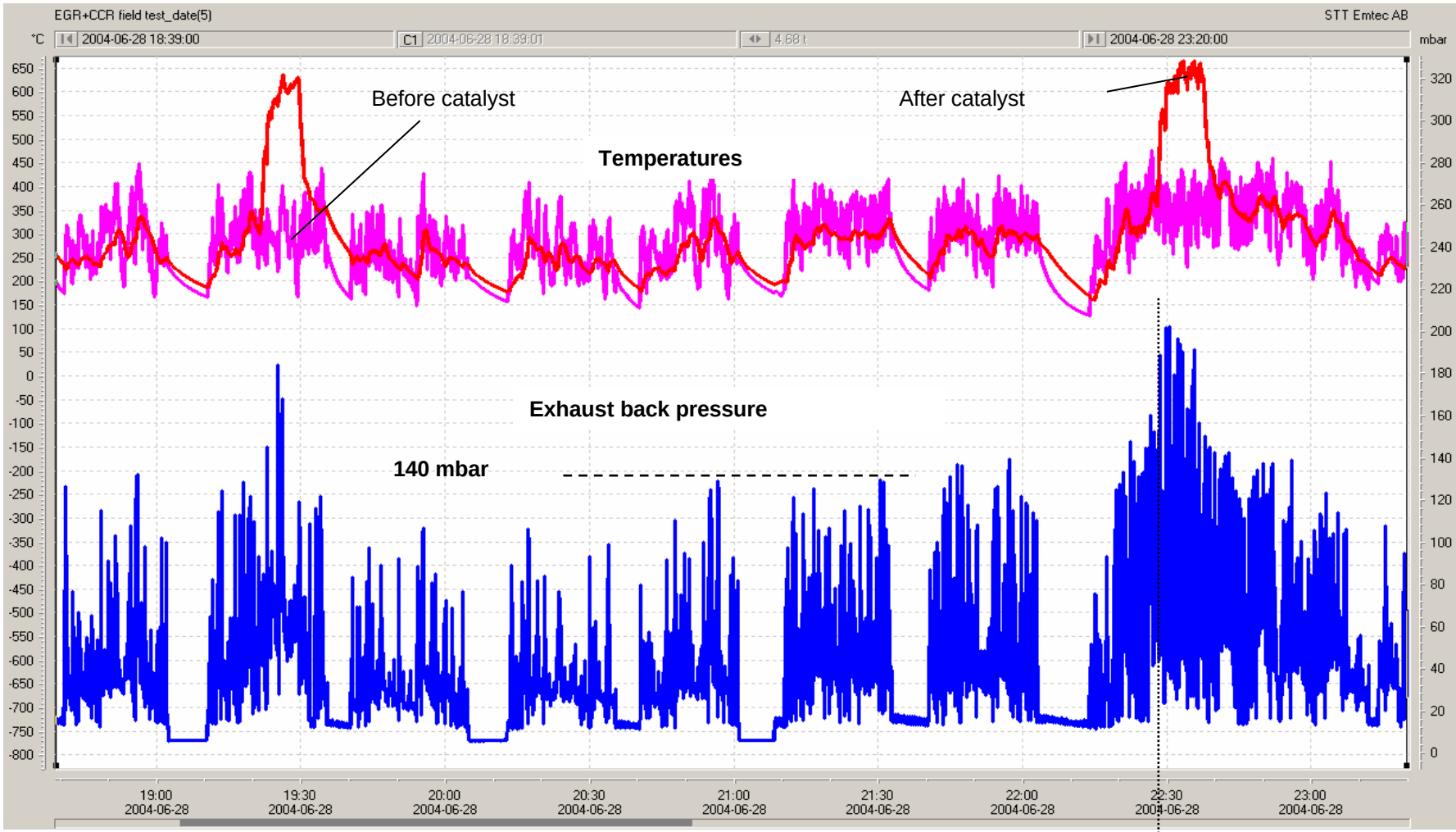


Active Regeneration of CRT with Fuel Injection System



Courtesy: stt emtec

Active Regeneration of CRT with Fuel Injection System



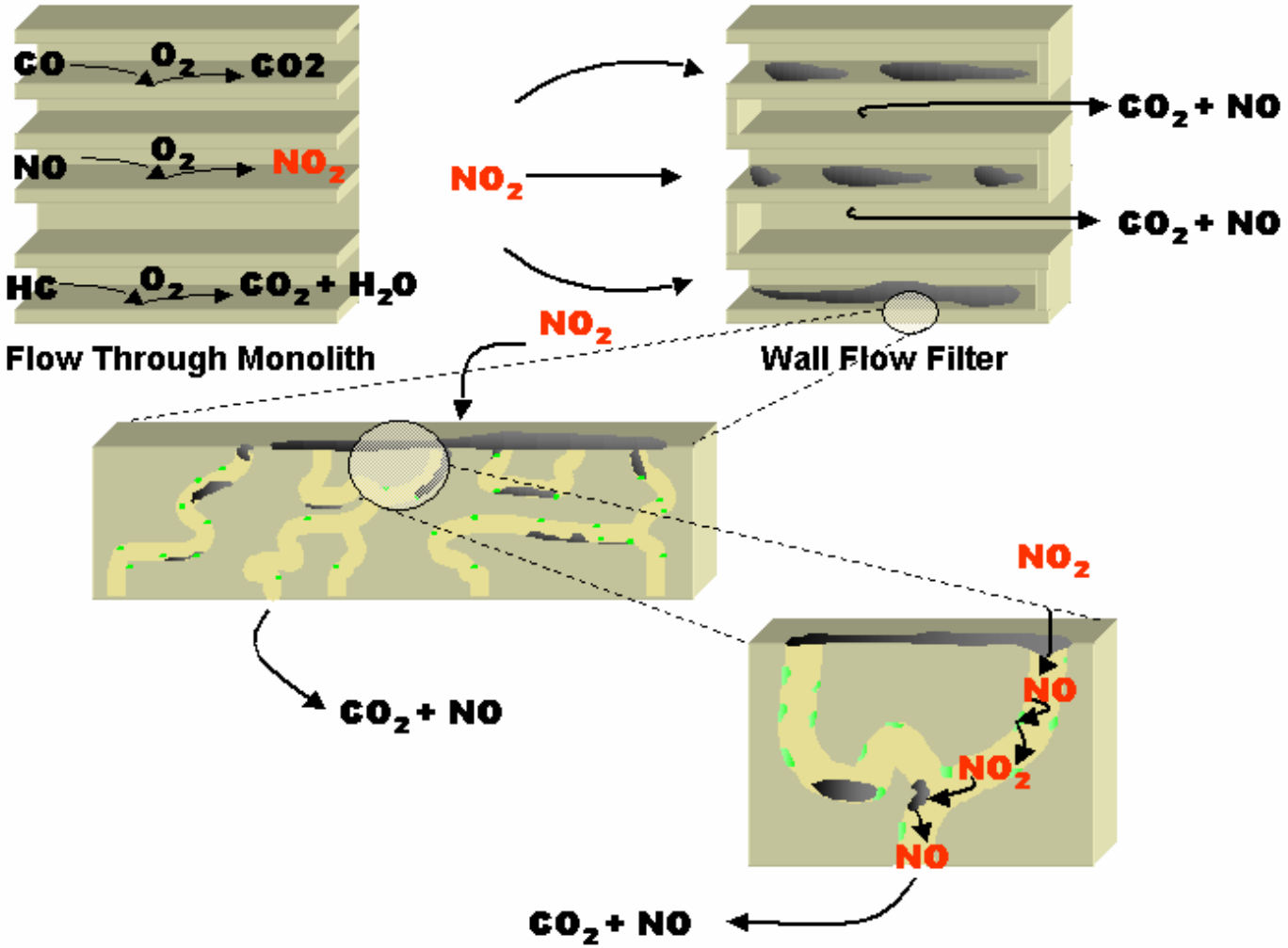
Courtesy: stt emtec

CCRT™ Filter System with Passive Regeneration

CCRT™ – An Advanced CRT for Challenging Applications

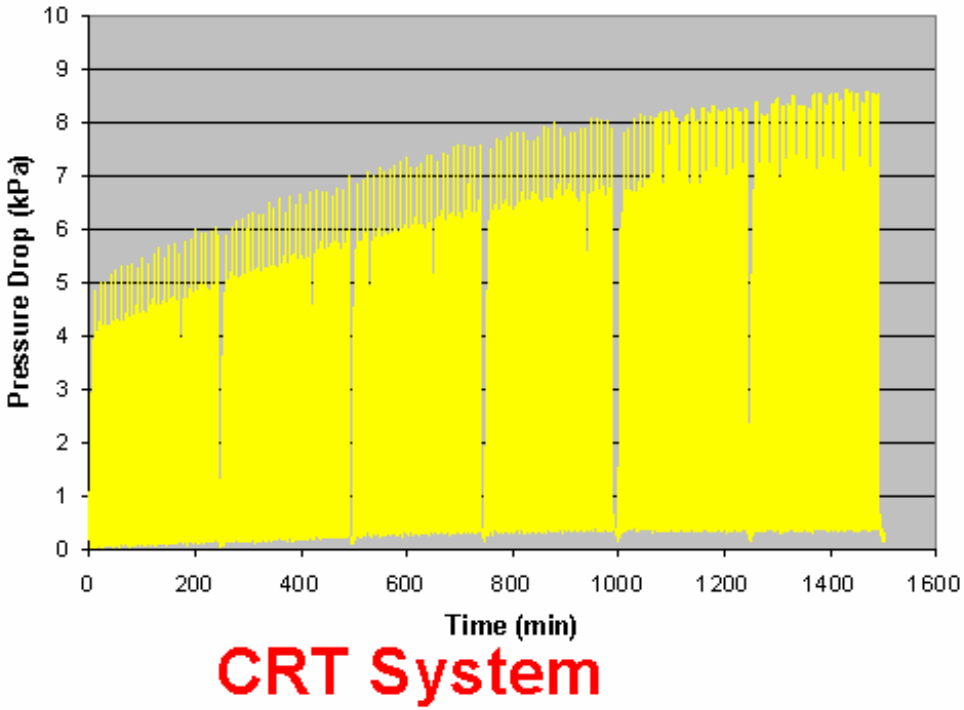
- CCRT = DOC + Catalyzed Filter
- Advantages of CCRT:
  - Higher soot burn rate than CRT or CSF
- Install in Challenging Applications
  - Low temperature applications (200 – 250oC)
  - Low NOx/PM applications (NOx/PM>15)
- Even at low CSF loadings, we see improved performance with the CCRT
- Successfully demonstrated in field trials in the US, Europe and Asia

CCRT System – Operating Principle



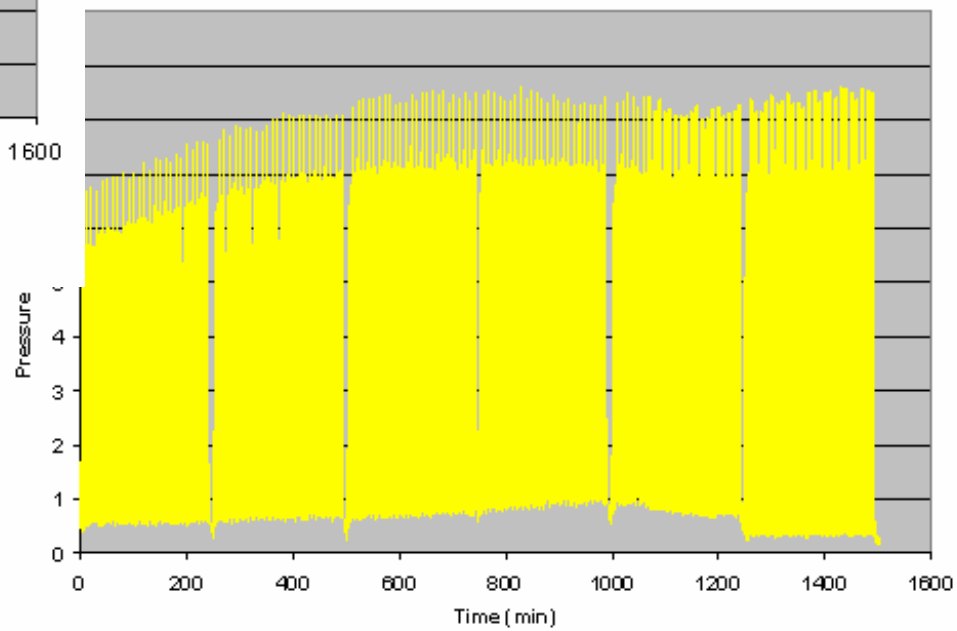
CRT Versus CCRT Stabilization Comparison

FTP Cycle, NOx/PM = 14

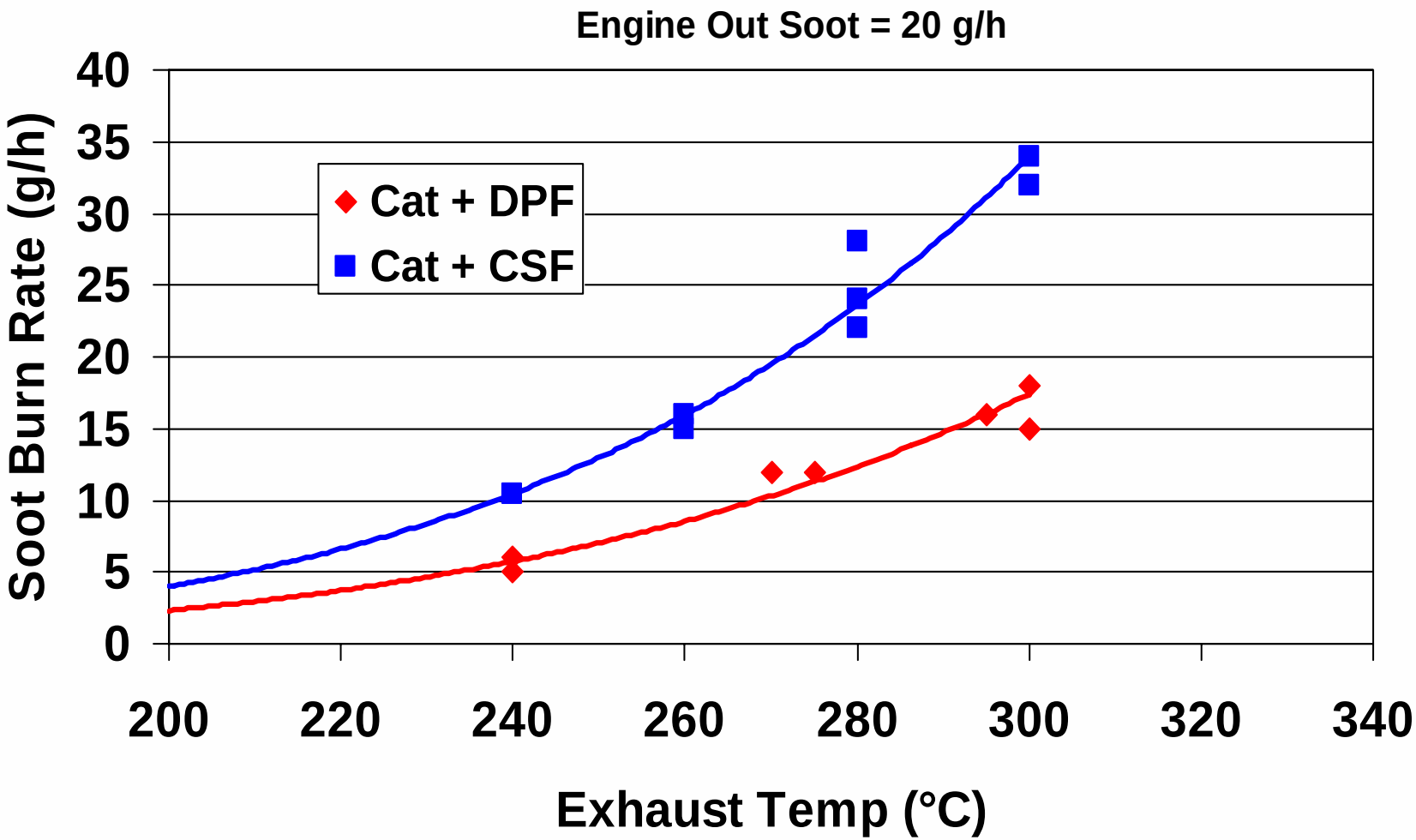


CRT System

CCRT System



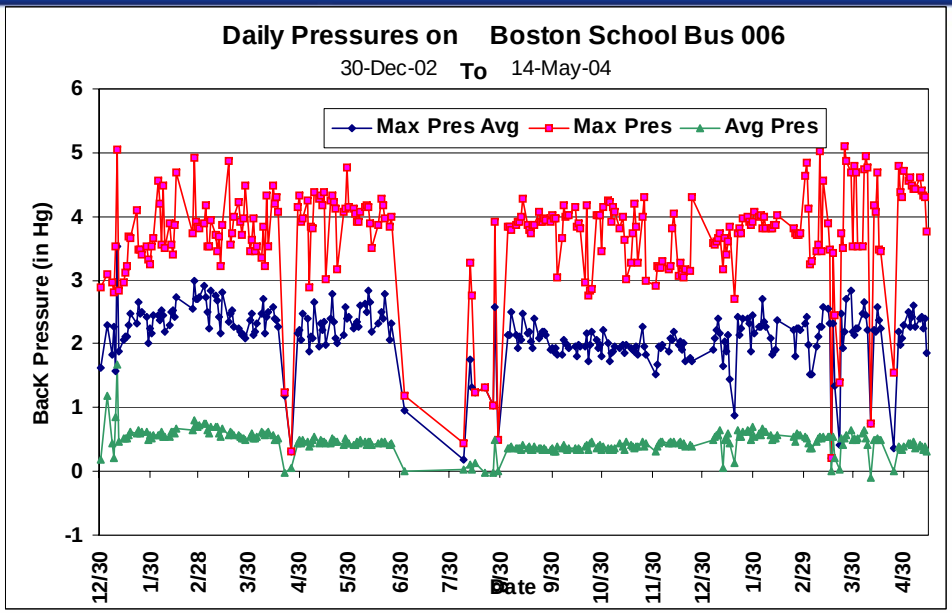
Soot Burn Rate Comparison for CRT and CCRT Transient Cycle Testing, NOx/PM = 15



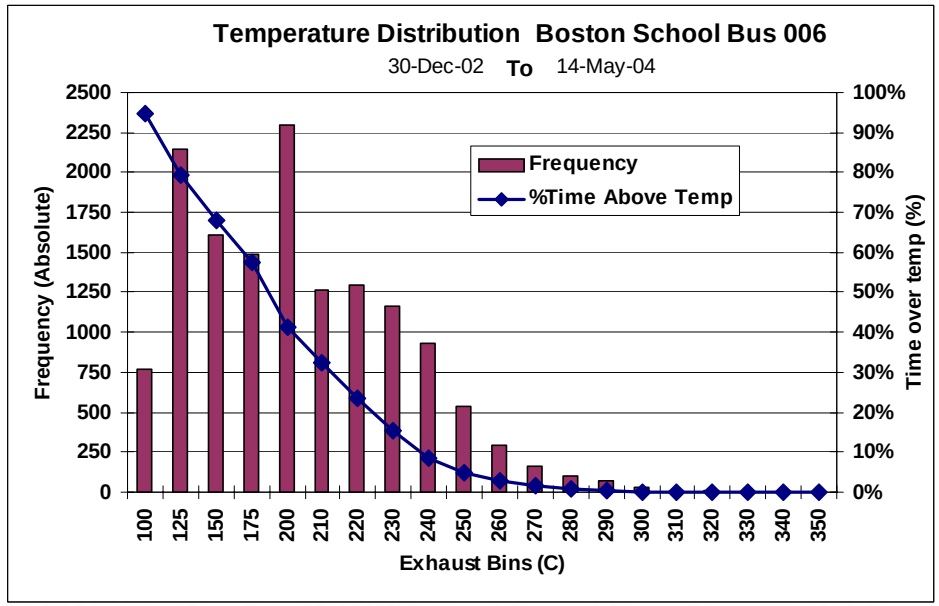
CCRT Field Operation:
Cold Temperature Applications

CCRT Experience on Low-Temperature School Bus

Boston School Bus with 175-hp 2000 MY CAT 3126 Engine

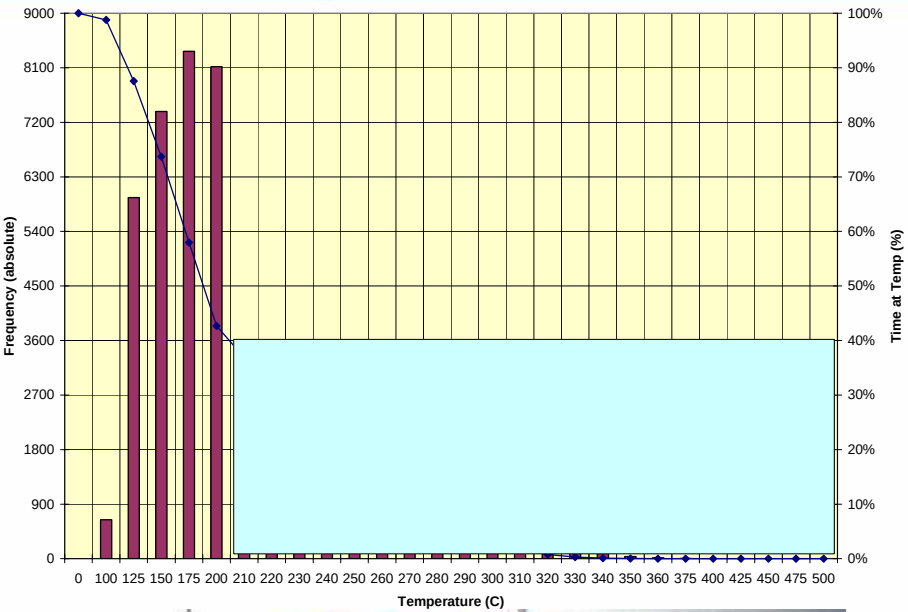


- Cold Exhaust Temperature Profile
- Only 8% of time Temp > 260 C; 40% time @ 200 C
- CCRT operating with stable back pressure for over 17 months

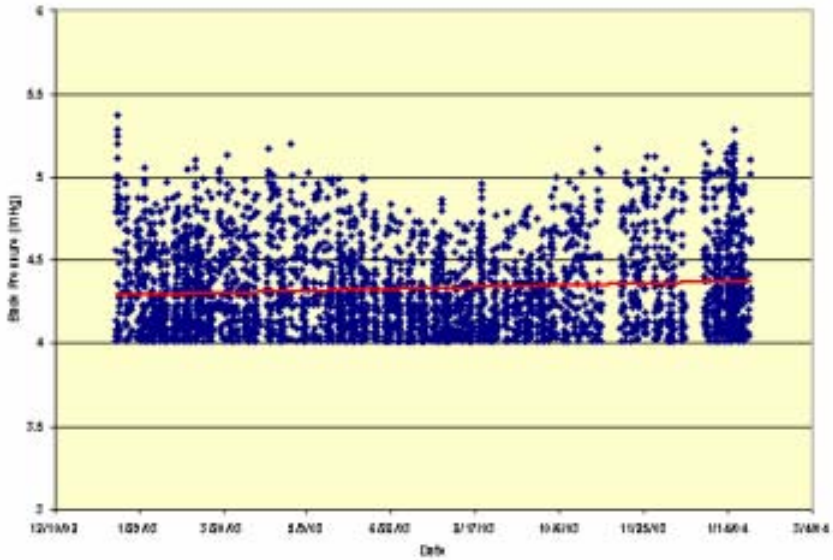


CCRT Experience on Low-Temperature Delivery Truck

Yosemite Water Truck with 190-hp Intl DT466 Engine, FT Fuel

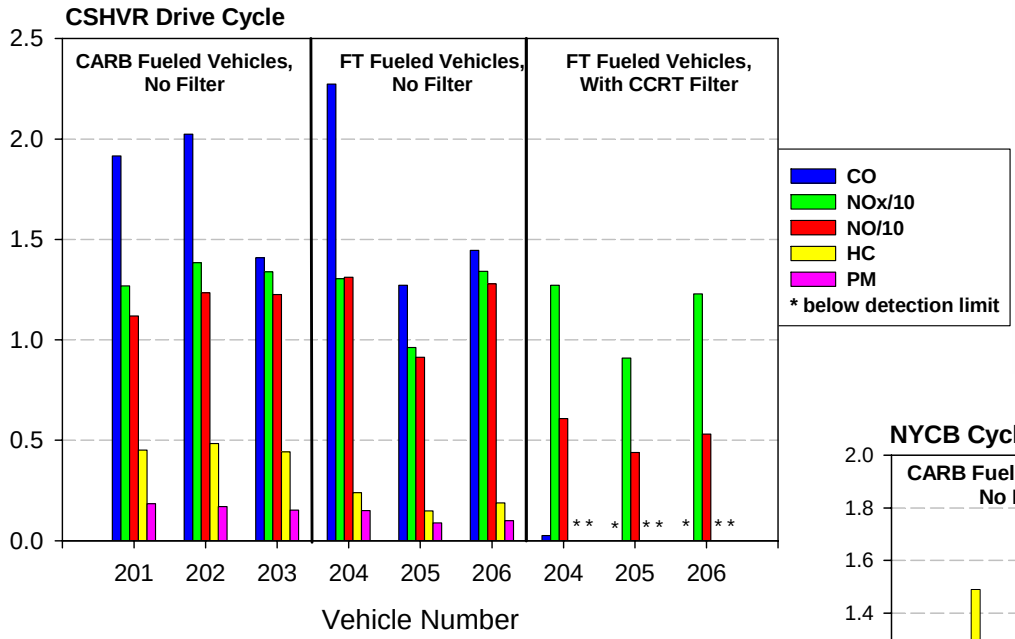


- **Cold Exhaust Temperature Profile**
- **13% of time Temp > 260 C**
- **CCRT operating with very stable back pressure since Jan 2003**



Chassis Dyno Emission Results

2001 International DT466 190hp, CCRT with FT fuel

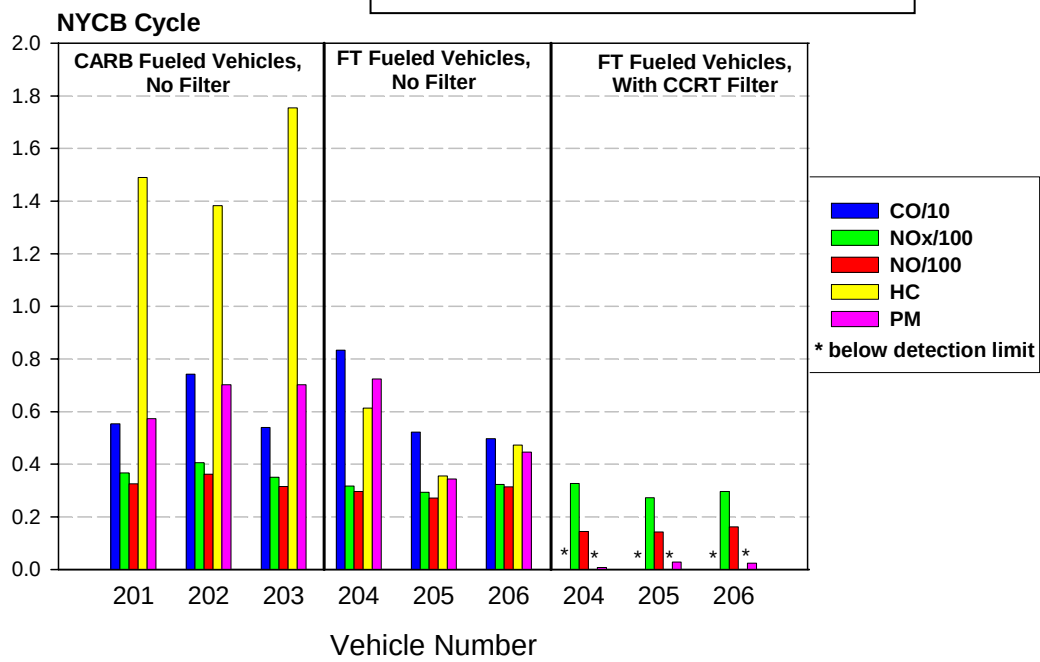


Emission Reductions CSHVR:

CO: 99.5%

HC: 100%

PM: 99.4%



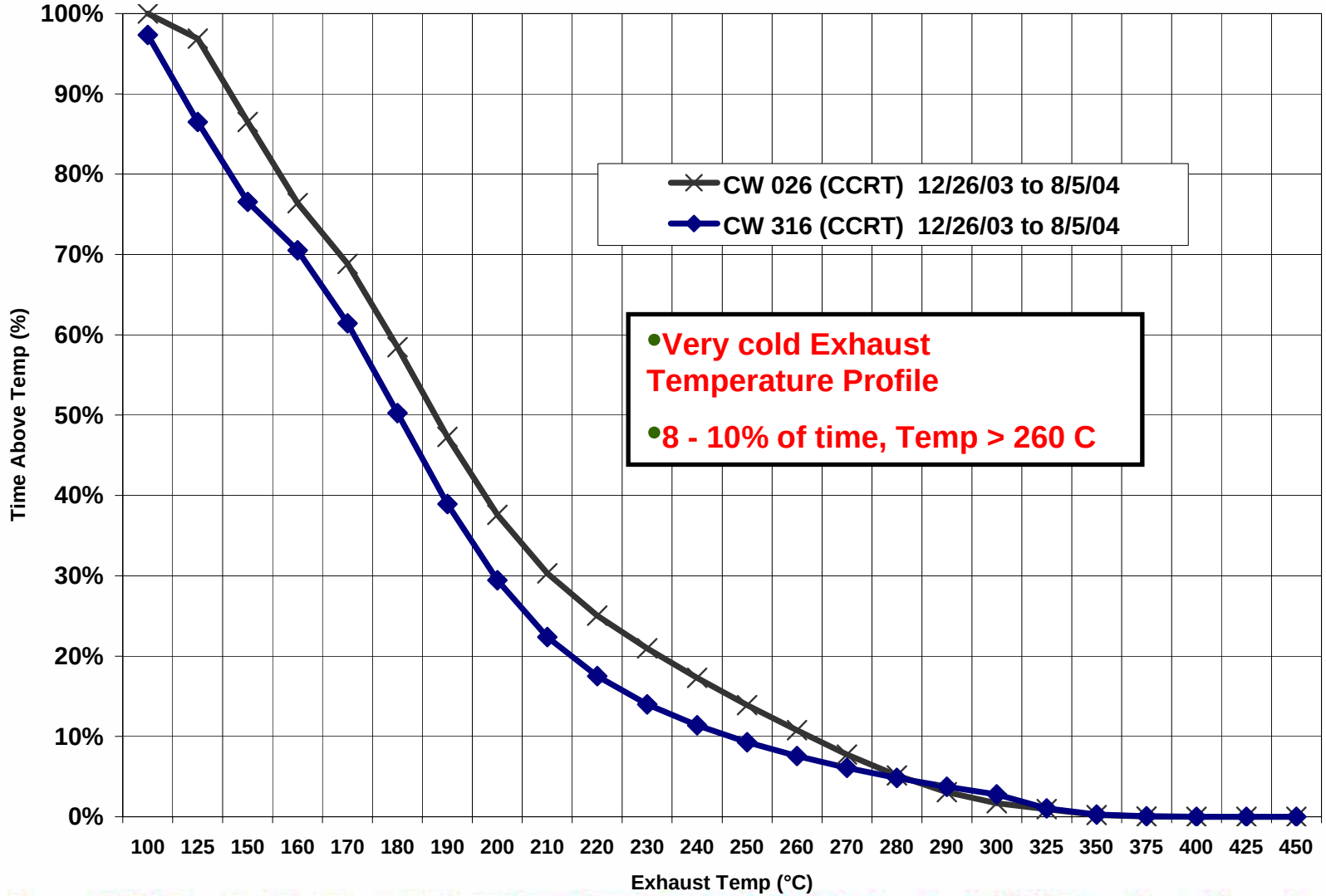
Emission Reductions NYCB:

CO: 100%

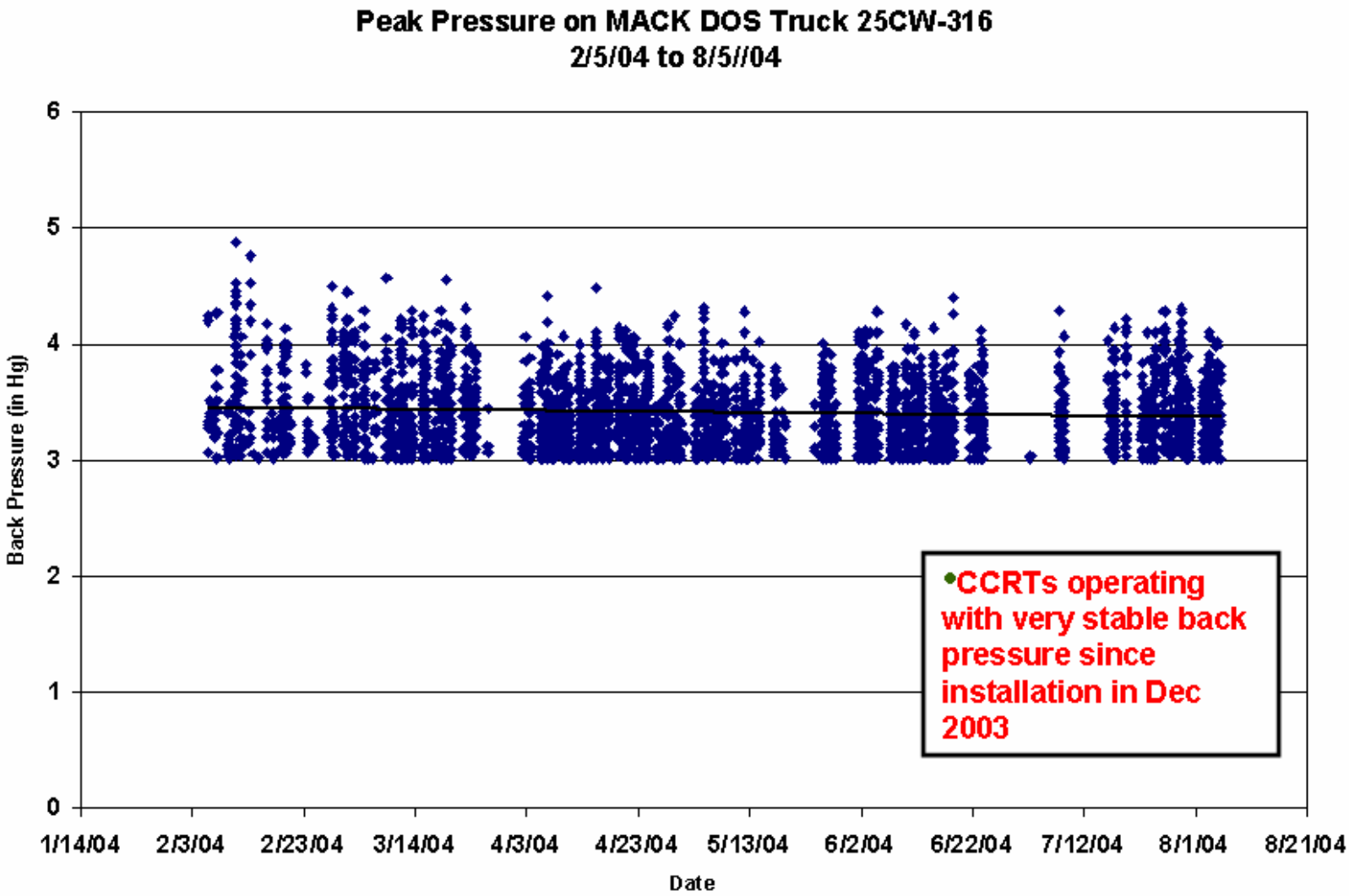
HC: 100%

PM: 96%

CCRT Installed on NY City Trash Trucks with Mack E 7 Engine – Very Cold Operating Temp.



Stable Operation of CCRT on NY City Trash Truck with MACK E7 Engine



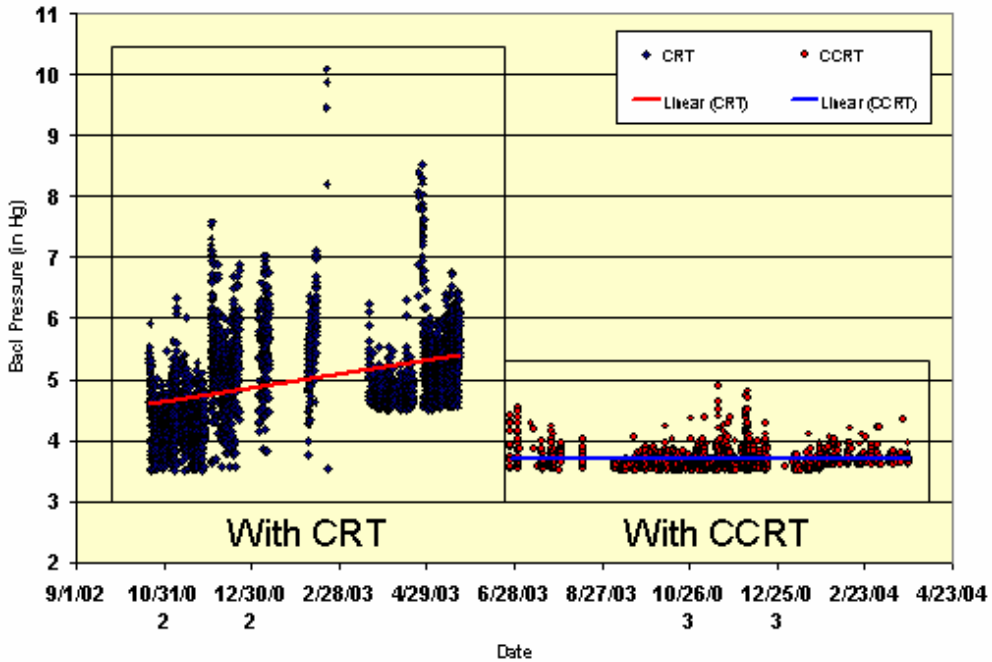
CCRT Field Operation:
Low NOx/PM Applications

CCRT Benefit over CRT on Low-NOx/PM Engine

8-L Engine 10.5 x 12 CCRT

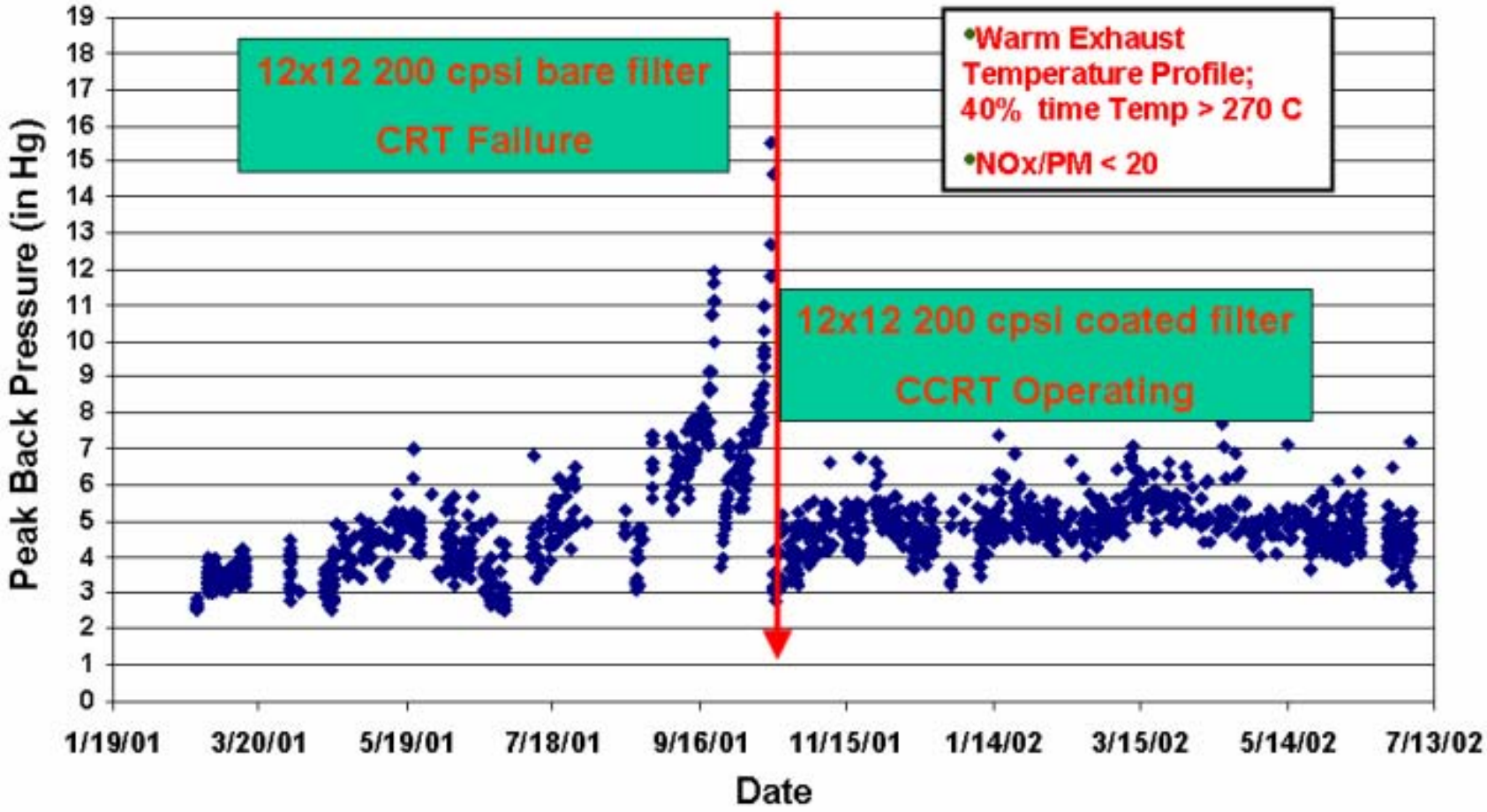
- Under FTP NOx/PM = 30
- Under some operating conditions NOx/PM drops to < 10.
- CRT would plug with soot in months
- CCRT operating successfully for over 12 months.

- **Exhaust Temperature 40% of time Temp > 320 C**
- **NOx/PM suspected << 20**
- **CCRT operating with very stable back pressure**



CCRT Benefit over CRT on Old, High-PM Engine

California School Bus with 2-Stroke Engine



Conclusions

- Low temperature and low NOx/PM ratio engine - challenging applications for DPF installation
- However, advanced DPF systems utilizing active and passive regeneration strategies can be successfully used in challenging applications
- Successful active regeneration systems include air restriction and fuel injection methods
- But, complexities with active regeneration systems; Fuel penalty, higher cost
- CCRT with advanced passive regeneration strategy has been demonstrated to be successful in such challenging applications
- CCRT can work:
  - T 40% @ 200 – 210 C
  - NOx/PM > 15

Acknowledgments

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- Environment Canada

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